SYSTEM SUPPORTING STORAGE DEPLOYMENT FOR THE COMPENSATION OF GRID EFFECTS CAUSED BY PV IN A DISTRIBUTION GRID

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***Abstract*— Distribution systems with long line distances and high shares of renewables in far out branches of the grid are regularly faced with problems concerning violation of voltage limits. This is a limiting factor for increasing the share of renewable energy sources (RES) in the system, thus a remedy for that issue will be needed. By using load flow calculations, the effects of an increased share of RES on a rural distribution grid are investigated. To resolve the negative effects on nodal voltage levels, one or multiple battery storages will be placed in the grid, featuring different deployment strategies. By placing a centralised storage with a system supportive deployment strategy, in opposition to decentralised small storages used to solely increase own consumption of RES, the voltage levels will be reduced and a higher share of RES can be integraded. This leads to the conclusion, that by using storages in a system supportive manner, the share of RES can be increased and the strain on the grid reduces. Therefore, measures to eliminate the barriers for system supportive storage deployment need to be taken in the future.**

Keywords - storage systems; renewable energy sources; distribution grid; voltage level control; system supportive storage deployment

I. INTRODUCTION

The increased share of renewable energy sources in the energy system is leading to a multitude of challenges. These challenges occur in all different parts of the grid, ranging from transport issues in higher grid levels, to voltage issues in lower grid levels. High nodal voltages occur due to renewable overproduction as a result from the decoupling of load and RES production. Especially rural distribution grids face the challenge of keeping the required standards for voltage quality. One of the key limiting factors is the voltage level, which experiences increased values well at the border of the limits set in [1]. In order to keep voltage quality standards, the thresholds for voltage increase through decentralised generation units may not surpass 2 % of the nominal voltage level for medium-high voltage and 3 % for low voltage levels. The basic equation for calculating the increase in voltage $\Delta U_{node}/U_{nominal}$ is shown in (1). It is dependent on the change of the active power ΔP_{node}, the change of the reactive power ΔQ_{node}, the line resistance R_{line}, the line reactance X_{line} and the nominal voltage level $U_{nominal}$.

$$\Delta U_{node}/U_{nominal} = (\Delta P_{node} * R_{line} + \Delta Q_{node} * X_{line})/U_{nominal}^2 \quad (1)$$

Rural distribution grids are often characterised by long distances between nodes, which also contributes directly to the increase in voltage levels.

Thus the question is how to tackle the arising challenges. Local RES deployment often happens at household level with the goal to reduce RES overproduction and increase the self-consumption of renewable energy. Increasing the own consumption can also be seen as reason for the implementation of a battery storage at one's home. One has to ask, if these measures are sufficient to not only reduce local renewable surpluses but also contribute to the challenge of keeping a high voltage quality. In this paper the focus is set on the contribution of battery storage systems providing relief for distribution grids and committing to supply quality:

- It will be shown in Section IV.D, that through the inclusion of system-supportive storage units the share of RES in a rural distribution grid can be increased.
- The choice of the storage deployment strategy has a major effect on the contribution of storages on the voltage quality. While a user based strategy of increasing the own consumption of RES production generates most benefits for the user, the effects on the system are practically non-existing, which is proven in Section IV.B.
- A centralised storage deployment strategy on the other hand, will yield the maximum benefits for the system while trying to reduce the overproduction from local RES units. The results of this analysation can be taken from Section IV.B.
- The location of the battery storage is an influencing factor when it comes to the effects of the voltage quality. The results of the research show, that the

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closer the storage is located to the cause of voltage level increases, the heavier the impact. This is shown in Section IV.C.

To obtain these results, an AC load flow model was implemented as described in Section III. The model is used to calculate different cases, described in detail in Section III.C to obtain the required results, which will be mentioned in Section IV.

II. Description of the Problem at Hand

The effort of the EU to decrease the amount of CO_2 emissions until 2030 by 40 % in comparison to 1990 [2] can only be reached by raising the energy efficiency of the system and increasing the share of renewable energy sources. This is also reflected on the electricity sector, where the share of RES such as wind power and PV is experiencing a steady growth. This development doesn’t come without problems, as the volatile and supply dependant character of RES production results in challenges for the electricity supply system. On lower grid levels in Austria an increase in PV generation capacities can be observed, ranging from roof mounted PV systems with an installed capacity in the single digit kW_p range to open-field PV power plants with capacities of multiple kW_p up to MW_p. In Austria about 11.7 % of the installed PV capacities are open-field PV power plants, the rest being mounted on buildings [3]. Due to the required space for the installation of PV units, in Austria the range lies between 1100 and 1400 kWh/m², these units will often be found in rural regions.

A. *Effect of RES infeed on the grid*

Due to the sparse population density in rural region the infrastructure of the electricity supply is not as meshed as in urban regions, featuring long distances between different consumers or consumption centres. As a result of the physical conditions in a grid, see (1), an increased power injection into a node of the grid leads to an increased voltage level. The height of the voltage level increase depends directly on the active and reactive power as well as on the resistance and reactance of the lines. Long lines with high resistance and reactance values will therefore lead to a disproportionate increase in voltage levels. In order to maintain a high level of voltage quality, thresholds for voltage level increase, due to power infeed into the grid, are defined in Austria [1]. For low voltage level the relative increase of voltage, adds up to 3 % related to the rated voltage and 2 % for medium-high voltage levels. These thresholds were implemented to ensure the adherence of the general limit for voltage level deviation of ±10 % of the rated voltage level, which was introduced to ensure functionality and prevent damage to end devices. Therefore, the voltage limits for generating units set a hard limit for the amount of renewable energy sources in grids.

B. *Challenges*

As a result, it will be necessary to find methods for the compensation of high voltage level increases due to RES generation. This will then allow to increase the share of RES in the system even further. This will ultimately lead to a more eco-friendly and sustainable energy supply. The problem itself concerns distribution system operators as well as individuals and companies willing to invest into renewable energy sources and will get more prominent as the share of RES increases.

III. Method and Data

In order to tackle the challenges arising from the high share of renewables in the system, additional flexibilities are needed to prevent surpluses of renewable energy sources and therefore keep the changes in voltage levels in check. The general incentive is to investigate the capability of battery storage systems to be used as system support to reduce the voltage variation peaks.

A. *General approach*

To get viable and realistic results an existing rural distribution grid, which features the general characteristics of long line distances and RES generation focus points in far out branches of the grid, is set as fundamental basis for the investigation. By increasing the amount of PV generation in that part of the grid, the point where the voltage levels surpass the thresholds is identified. To calculate the voltage levels, AC load flow calculations are performed for each quarter hour of the year, from which the maximum annual peak voltage increase can be derived. Two different approaches for increasing the PV generation are chosen, one featuring a concentrated increase at a single node of the grid where an open-field PV power plant is already installed. For the other approach roof mounted PV generation units on residential buildings are chosen.

The next step will be to insert different battery storage systems into the grid and evaluate the effects of the storage use on the resulting voltage levels. The method of implementing the storages mirrors the approaches for increasing the PV generation capacities. For the approach of distributed PV generation increase, smaller battery storage systems are implemented on household level, whereas for the concentrated approach one centralized storage system of higher capacity is inserted. The chosen approach also reflects on the storage deployment strategy. Since the distributed storage systems are building bound, only the location of the centralised battery storage system will be changed in the grid to investigate the effects of different deployment locations. With the results of the storage deployment, new calculations of resulting voltage levels will be undergone, with the goal to highlight the effects of different storage sizes, deployment strategies and storage locations on the voltage quality. Again AC load flow simulations will be used to calculate the resulting nodal voltage levels.

B. *Considered data*

The distribution grid, which serves as case study for the research, has a nominal voltage level of 20 kV and consists of 26.3 km of overhead lines, 26.2 km of cable lines as well as 56 consumption-nodes, see Fig. 1 Figure 1. for a simplified display of the grid. The nodes marked with n_x highlight the region with a very high share of RES. Additionally these nodes also show the highest possible distance from the connection 110 kV grid, which maximises the effect of RES surplus on voltage level increase. In the base case analysation, this part of the grid is characterized by a 500 kW biogas power plant installed at node n_5 and approximately 510 kW_p PV capacity installed at different nodes (n_1 to n_5).

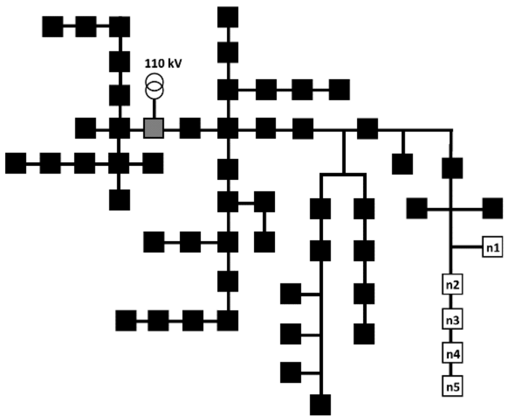

Figure 1. Simplified visualisation of the distribution grid used in the present research study

This total generation capacity of 1,010 kW stands in comparison to an annual peak load of 600 kW. This gives reason to believe, that throughout a year a multitude of situations where the current generation surpasses the current demand will occur, thus giving a high potential for renewable surpluses. The described situation will further on be referred to as *Base-Case*.

Besides the grid itself, quarter hourly values for loads and generations are used, with each 20 kV node serving as an aggregator for the consumers and producers connected to it. For consumers and producers with an installed load profile meter, the corresponding data is used. The other consumers in the grid, are represented by their corresponding standardised load profile. Through AC load flow simulations using the MatPower [4] toolbox for MatLab the load flow and nodal voltage levels for each time step are calculated, leading to 35040 sets of results. Due to missing data, the reactive power in the system is neglected and only active power values considered.

To be able to calculate the increase of the voltage levels due to power infeed into the system an additional case has to be calculated, where all generation capacities are taken out of the system. This so called *Case-Zero* will be used as baseline for the calculation of all relative nodal voltage level increases.

In order to calculate the limits of the distribution grids, when it comes to increasing the shares of renewables, two methods of adding PV generation capacities are chosen. For the first method *Case-Centralised* the additional PV generation is installed at node n_4 where a PV power plant of 350 kW_p is already installed. For the second approach *Case-Decentralised* the additional PV generation capacity is distributed amongst the residential buildings in the rural area. To scale the installed capacity of each distributed PV generation unit, the annual energy consumption of each household is considered. It is used to generate a load curve using the standardised load profile H0 [5]. Assuming that households with a higher annual consumption will be more likely to install a PV unit to reduce their electricity bill, the PV generation increase is started at these households. The PV generation profile is calculated on basis of global radiation data using the simplified equation for PV-generation in (2), where the generation of the PV power plant P_{PV} is dependant from the area of the panels A_{PV}, the performance ratio $r_{performance}$, the efficiency of the panels η_{PV} and the global radiation E_E.

$$P_{PV} = A_{PV} * r_{performance} * \eta_{PV} * E_E \qquad (2)$$

The capacity of the PV generation unit is set for each household using increments of 2.5 kW_p until an own consumption rate between 30 % and 40 %, in compliance with the results from [6], is reached. The total installed PV capacity in this region of the grid is then increased by adding PV generation to one household at a time. This process is continued until the limit for the voltage level increase is breached at one of the nodes, resulting in an uneven distribution of PV generation capacity amongst nodes n_1 *to* n_5.

C. Deployment strategies for storage systems

To determine the effects of storage deployment in this case study, two different approaches in correspondence with the distribution of PV generation capacity are used. For the *Case-Decentralised*, each household is equipped with a single battery storage unit, taken from [7]. The aggregation of these single household storages is taken as an estimation for the parameters of the *Case-Centralised* storage, the exact model is taken from [8]. In accordance to the two different cases for storage integration, two different approaches for storage deployment strategies where chosen as depicted in Fig. 2.Figure 2. The graphs show the courses of residual load (3) with and without storage usage. The residual load $P_{Residual}$ depends on the values of the load P_{Load}, the current generation $P_{\mathrm{Generation}}$ and the current generation/load of the storage P_{Storage}.

$$P_{Residual} = P_{Load} - P_{Generation} + P_{Storage} \qquad (3)$$

The main goal for decentralised storage deployment in households is the increase of own consumption of PV generation, thus leading to a strategy, where the storage system will be activated once a surplus in PV generation is available. After the storage is completely charged, no additional surplus can be compensated by the storage. It will be emptied, once there is no surplus anymore and electrical power will be taken from the grid. The question arising at this point is, if the capacity of the decentralised storage units will suffice to also reduce the strain on the grid.

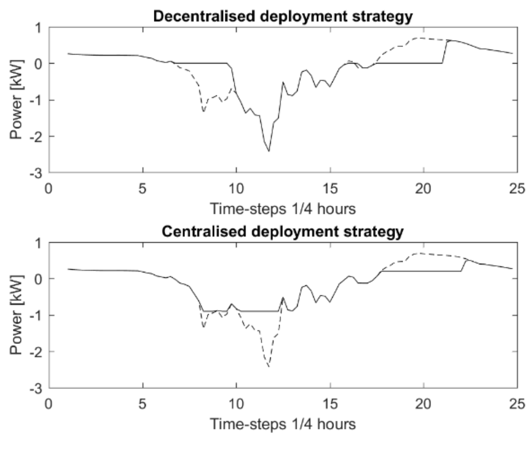

Figure 2. Storage deployment strategies for households (top) and centralised storages (bottom)

For the centralized storage deployment strategy, shown in Fig. 2, the storage system tries to reduce the highest generation surpluses by charging the battery. Whenever possible the storage system also tries to reduce the highest peak loads, by discharging the battery. But the emphasis is set on the reduction of peak RES surpluses. In order to simulate the storage behaviour corresponding models where formulated using MatLab and Simulink. The formula considers the maximum usable capacity of the storage, charging and discharging efficiencies η_C and η_D, the current charging and discharging power P_C and P_D as well as maximal capacities of the storage units to calculate the current charging level of the storage $E_{Storage}$, see (4).

$$E_{Storage}(t) = P_C(t)/\eta_C - P_D(t)/\eta_D + E_{Storage}(t-1) \quad (4)$$

For the *Case-Centralised* an optimisation of the charging and discharging behaviour using the simulation model was undergone, ensuring that the reduction of surpluses reaches the maximum, while still maintaining the highest possible reduction of peak loads. The target function, as a result of the current generation P_{Gen}, for values of $P_{Residual} <= 0$ is formulated in (5).

$$\text{maximise } P_{Residual} = P_{Load} - P_{Gen} + P_C - P_D \quad (5)$$

IV. RESULTS

Analysing the different cases proves the suspicion of rising voltage levels due to renewable generation in nodes n_1 to n_5. The results show, that the general limits of ±10 % of the nominal voltage levels are never breached. Nevertheless, the relative voltage level changes caused by the renewable energy sources in the discussed part of the grid, reached rather worrisome values.

Fig. 3 shows the results of this first calculation featuring the *Base-Case*. The relative voltage level changes in node n_5 reach a peak value of 1.5 %, which is within the bounds of 2 % for medium-high voltage grids, but doesn't leave much room for further increases. The highest observed voltage level reaches a value of 101 % of the nominal value, which comes up to an increase of 1 %, thus being well within the ±10 % limits.

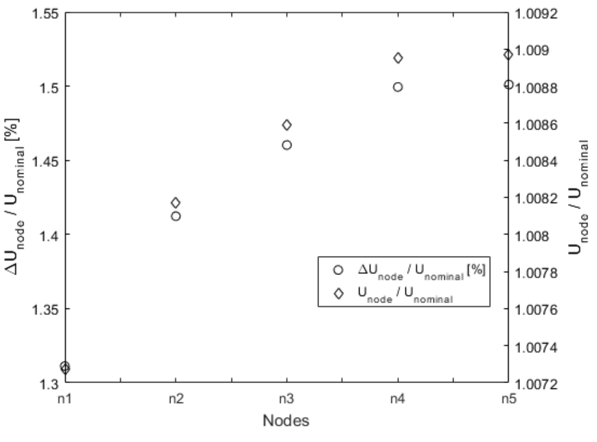

Figure 3. Absolute voltage levels and relative voltage level changes in the *Base-Case* calculation

Another result of the analysation of the *Base-Case* proves, that the voltage levels in the grid increase the higher the distance gets. At node n_1 the relative voltage change already reaches approx. 1.3 %. Therefore, the RES generation at nodes n_4 and n_5 has far reaching effects. From the results shown in Fig. 3 one can also derive, that the distance between nodes n_4 and n_5 is rather short, as both nodes feature a high amount of RES generation, yet the voltage levels are similar.

A. Effects of increasing the share of RES

By increasing the total installed PV capacity in nodes n_1 to n_5 by an additional 500 kWp the limits of +2 % for $\Delta U_{node}/U_{nominal}$ are breached. The highest voltage level changes occur in the case of centralised PV integration, reaching a value of 2.05 %. In both cases, either decentralised or centralised increase, the relative voltage level changes surpass the thresholds, leading to an unacceptable situation and calling for measures in the grid. As can be taken from Fig. 4, the voltage levels at each of the relevant nodes increase by approximately 0.5 % (between 0.47 % and 0.55 % depending on nodes and method of adding PV generation). There are small differences (between -0.02 % and +0.05 %) between the two cases of distributed or centralised increase. The reason being the different distributions of PV generation. All additional production capacity is added at node n_4 for the case of centralised PV integration. Whereas for the decentralised approach additional PV generation capacities are also added at node n_1. As node n_1 is not in direct line to the other 4 relevant nodes (Fig. 1), the voltage level is higher for the decentralised approach. But no matter the case, the violation of the limits for voltage increase exists at the farthest away nodes in the grid. Generally speaking it can be said, that for the investigated grid a distributed increase of RES is more suitable and leads to a lower increase in voltage levels.

To address the voltage issues the step of implementing storage systems into the grids needs to be undergone. Therefore, starting with the case of distributed PV generation, each household featuring a PV generating capacity is equipped with a storage system, designed and deployed to increase the own consumption. These storages will be using the decentralised deployment strategy, see Fig. 2.

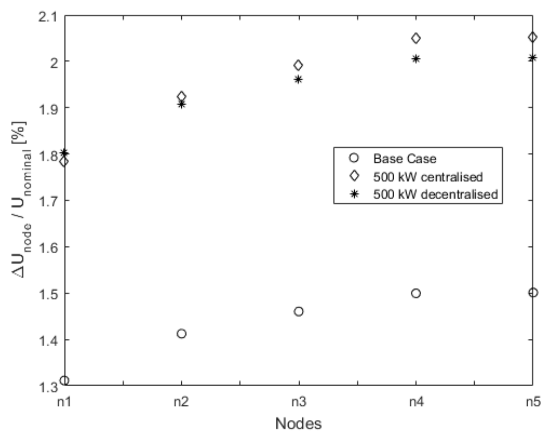

Figure 4. Comparison of relative voltage level changes due to the increased PV generation capacity

TABLE I. STORAGE SYSTEMS USED FOR INCREASING THE OWN CONSUMPTION OF PV GENERATION AT HOUSEHOLD LEVEL [7]

Storage systems for optimising PV own consumption			
Storage system	***Power***	***Usable capacity***	***Efficiency***
DESS P09B20-HC08	9 kW	17 kWh	90 %
BPT-S 5 Hybrid	5 kW	13.2 kWh	90 %
ASD Hybrid 13	4 kW	10.8 kWh	88 %
BPT-S 5 Hybrid	3.8 kW	6.6 kWh	90 %
SENEC Home 4.0 Pd	2.5 kW	4 kWh	92 %
Domus 3.0	3.0 kW	2.4 kWh	90 %

TABLE II. STORAGE SYSTEM USED FOR THE CENTRALISED DEPLOYMENT APPROACH [8]

Storage system for system support			
Storage system	***Power***	***Usable capacity***	***Efficiency***
IS 275/640	275 kW	448 kWh	90 %

The parameters of the storages implemented are chosen according to the parameters at the individual households, leading to the utilisation of the storage systems shown in TABLE I. The operation of the storage system leading to an increase of own consumption of an additional +20 % to + 30 %. Since the distributed approach for PV generation integration considers the annual energy demand of the buildings, different types and numbers of storages will be needed. In order to get comparable results between the distributed storage deployment and a centralised approach, these numbers of storages needed will be connected with their corresponding parameters and added up, defining the parameters for the centralised storage system. In a similar approach as for the decentralised storage system, a storage fitting the parameters calculated is chosen and shown in TABLE II.

B. Comparison of centralised and decentralised storage deployment

To be able to tell the effects of the different deployment strategies and PV integration methods, different cases are used. These are described as follows:

- Case dPV|dStore|dStrat:
  For both the PV generation and the deployment of the storage the decentralised approach is chosen, leading to a spread PV and storage integration at household level. The storage uses the decentralised deployment strategy aiming at increasing the own consumption of RES, disregarding the effects on the grid.
- Case cPV|cStore|cStrat:
  For both the PV generation and the deployment of the storage a centralised approach is chosen. With this case the additional PV generation is bundled at node n_4 as well as the storage system. The storage uses the centralised deployment strategy, focussing on the positive effects for the grid.
- Case dPV|cStore|cStrat:
  For the PV generation the decentralised approach is chosen, whereas for the storage a centralised approach is chosen. In accordance to the case cPV|cStore|cStrat, the storage is placed at node n_4. The storage uses the centralised deployment strategy.
- Case dPV|dStore|cStrat:
  For both the PV generation and the deployment of the storage the decentralised approach is chosen. The storage on the other hand, uses the centralised deployment strategy. This case should highlight if it is sensible to use decentralised storage systems as benefit for the grid. As the required energy management system needed to facilitate this strategy can only consider the parameters of the household using the storage, the effects of the locally installed PV generation on the grid will be minimized.

The effects of using the storage systems can be seen in Fig. 5, where the results of the four cases mentioned above are compared to the results of PV increase without the use of storage systems. The results show clearly, that for ***Case dPV|dStore|dStrat*** no effects on the voltage levels can be seen. This result suggests that the capacity of the storages doesn't suffice to also contribute to the voltage quality. Whereas the other cases, each characterised by either a centralised storage or a centralised strategy, have positive effects on the voltage levels. The best effects can be reached in ***Case dPV|cStore|cStrat*** resulting in the lowest possible voltage levels. This is partially the case due to the generally lower levels while using decentralised PV generation increase.

When comparing the different use cases of storage deployment strategy and utilisations methods with the corresponding PV implementation methods the reductions are very similar, reaching values of up to -0.2 % for both the centralised and decentralised increase of PV generation capacity. Therefore, the storage system provides comparable reduction effects for the cases ***Case cPV|cStore|cStrat*** and ***Case dPV|cStore|cStrat***. Hence it can be concluded, that a centralised storage system featuring a centralised deployment strategy leads to a comparable reduction of the strain on the grid. Consequently, it can be used in both cases.

An interesting result can be derived from looking at the results of ***Case dPV|dStore|cStrat***, where the decentralised storages use a centralised deployment strategy on local level. In contrast to being installed in a distributed manner, the storages are still trying to prevent strain on the grid. The effects of that deployment are without any doubt positive, as the voltage levels are kept within the regulatory limits, but the resulting reductions are not as high as in the cases with a centralised storage system.

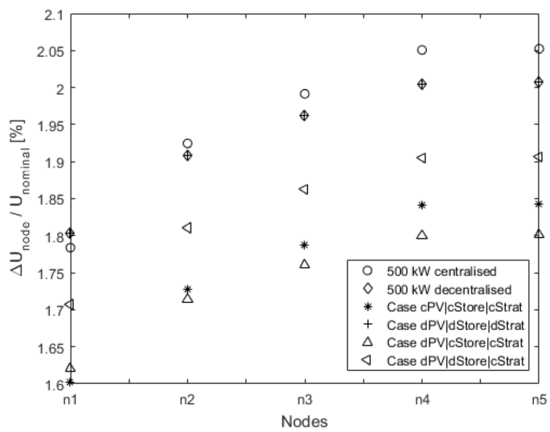

Figure 5. Effects of the voltage level increases due to using the different deployment strategies for storages

The reason behind the results not being as good compared to the centralised storage system, lies in the fact, that the local PV generation on household level is not the main reason for high voltage levels. Often the surpluses of one household get compensated at the same node by other consumers. As a result, they won't contribute to the situations where the surplus responsible for the high voltage levels occurs. Another factor is, that the single storage systems will reach their limits at different times, whereas one big centralised storage can use its entire capacity in a more controlled and coordinated way.

C. Dependancy of storage location

Given the proof, that the decentralised deployment of the battery storage systems takes hardly any to no effect on the voltage level issues, the centralised approach gives more promising results. To proof the consequences of placing the storage at different locations, corresponding calculations are executed. The results of the variation of the storage location are shown in Fig. 6. There is a correlation between the location of the storage and the effects it takes on the grid. This can clearly be seen, by observing the effects from a storage placed at node n_1. Where the voltage level increase is lowest for node n_1 but higher for every other node. The effect occurs due to the structure of the grid, while node n_1 also experiences high values for voltage increase, they are the lowest in the relevant region, as node n_1 is the closest to the 110 kV node, see Fig. 1. Node n_1 is also not in line with the other relevant nodes but rather parallel. Thus a reduction of voltage levels in node n_1 only has a limited effect on the other nodes.

The main causes for the increase in voltage levels are the generation in node n_4 and n_5. Placing the storage at these nodes yields the best results for the reduction of the voltage level increases.

The differences at each node are rather small, ranging from +0.0064 % at node n_1 and -0.0129 % at node n_5 (results for placement at node n_1 vs. placement at node n_5). Nevertheless, the assumption, that the location of the storage system has an effect is proven. It is also suggested that the location of the storage system should be as close as possible to the farthest cause of voltage level increases.

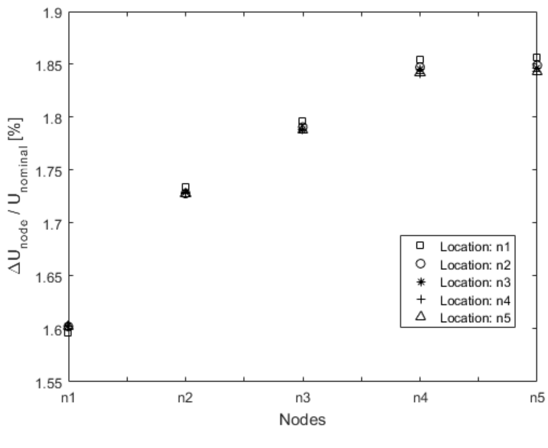

Figure 6. Effects on the voltage levels as a result of changing the storage location

D. New room for additional RES capacities

The investigation shows, that the system supportive deployment strategy for storages has a positive effect on the voltage levels in the grid. Positive effects can be derived from both the decentralised as well as centralised location of the storage. The voltage level reduction through using the storage(s) reduces the levels beneath the critical value, thus allowing more RES to be integrated into the grid. In comparison to the cases without the use of storages, a decrease in voltage level change of up to 0.2 % at node n_5 can be reached. This voltage level decrease allows for approximately 200 kW_p of PV generation to be installed. Which strikes as odd, as the installed power of the storage system of 275 kW would suggest that the same amount of additional PV generation can be integrated into the system. It seems like the energy capacity of the storage (448 kWh) is the limiting factor preventing a reduction of voltage level changes to the full power capacity (275 kW) of the storage system. Therefore, it must to be assumed, that an increase in storage capacity, while keeping the power of the storage at the same level, yields better results. One should ask if the trade-off would be worth the effort.

V. RELATED WORK

The investigations done in this paper were kindled by research of other institutions, giving the incentive to acquire deeper knowledge on how different storage deployment strategies can take influence on the voltage levels in a distribution grid. [9] shows, similar to the results in the present paper, that the deployment strategy of the storage system has a major effect on the voltage level reduction. The study investigates the effects of PV overproduction through using a 25 node model with identical loads and generation values at each node. This produces an extreme case. The study shows, that a storage dispatch for own consumption increase has hardly any effect on the voltage levels. Whereas a system oriented dispatch, similar to the one used in the present paper, has positive effects.

The idea of using storage systems, or flexibilities in general is not new. [10] addresses this issue by defining the positive effects of decentralised battery storage systems for a stable electricity supply. The publication defines different deployment strategies for battery storages, leading to different uses within the system. Also the use of storage systems to tackle the challenge of voltage quality is described. Aside from the method used in this paper, by actively influencing the active power contribution of the storage, [10] static voltage control by providing reactive power and dynamic voltage control by providing short circuit power to the system are listed.

[11] sets the focus on the influence of different storage deployment strategies on the grid feed in for PV storage systems, leading to similar results as the investigation in this paper. Through using a storage deployment similar to the centralised deployment strategy in the present paper, the amount of RES which can be included in the system is increased. These results are gained by using widespread data for PV generation in Germany with a very high resolution of time data.

VI. CONCLUSION

The present research work sets the focus on the effects of implementing storage systems into a rural distribution grid in order to be able to increase the share of RES without breaching the limits for changes in voltage levels. The ability to provide flexibility will be even more important than today because of an increasing amount of fluctuating and supply dependant renewable energy sources, driven by political and personal goals of reducing the strain on our environment.

By integrating storages into the electricity system the negative side-effects of increased voltage levels can be partially compensated. Even though the full installed power of the storage cannot be utilised, as the capacity of the storage system limits the deployment. To achieve this compensation, the deployment and utilisation of storage capacities needs to be directed toward providing system support, rather than maximising one's own economic profit. Rural distribution grids have limits when it comes to increasing the amount of renewable energy sources. These limits serve the purpose to protect electric components by keeping the voltage levels in bound. To keep the voltage levels within these limits, RES surpluses, which are the main reason for voltage peaks, need to be reduced or prevented, thus leading to the conclusion that any flexibility should be used to address these peaks. Additionally, when it comes to placing the storage system(s) within the grid, the proximity to the cause of the surplus is of essence. The flexibility should always be provided as close to the cause for surpluses as possible, preventing them where they occur. This leads to an interesting dilemma for storages implemented in households. Since they can only be used for the local prevention of surpluses, they have less impact on the grid. Even when considering a system supportive deployment strategy, they can only be a real remedy for voltage level peaks, if the RES generator of the household is responsible for the RES surpluses in the entire region. With a system leaning towards a higher share of renewable energy sources and the high costs of storage systems, the deployment and utilisation should be well planned and executed.

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